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PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventors: CHARLES ANDREW GROTZ, WILLIAM ARTHUR REINHART and
KENNETH VIVIAN SWANKE



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COMPLETE SPECIFICATION

Noise Suppressor for Jet Propulsion Engines

We, BOEING AIRPLANE COMPANY, a corporation of the State of Delaware, United States of America, of 7755, East Marginal Way, Seattle, King County, State of Washington, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to noise suppression devices for jet propulsion engines of the gas stream thrust reaction type having a discharge nozzle with an exit through which exhaust gases are discharged to produce forward thrust.

The present application has been divided out from Application No. 19877/58 (Serial No. 859,993) and in general the present invention achieves jet engine noise suppression by the same basic approach as that employed in the above-cited application, namely, that of dividing the discharge stream into a plurality of separate or branch streams at the nozzle exit. This division of the main jet into a number of smaller jets, particularly when these are spaced apart about the periphery of the nozzle exit, decreases objectionable noise in two ways. First, it reduces the total noise level, and, secondly, it shifts much of the residual noise to higher frequencies at which the effect on the human ear is less noticeable.

When the main discharge stream from a jet engine is divided into a plurality of separate streams at the nozzle exit a certain reduction of nozzle efficiency takes place. This is due to the obstructive effect and friction losses incurred by the stream dividers. In some applications the thrust loss is not serious and the stream dividers are a fixed and integral part of the nozzle. In other

applications, however, with which the present invention is also concerned, there are times when full engine efficiency, obtained only with an unbroken circular or similar regular exit configuration, is necessary and is more important than noise suppression. It is therefore desirable in such instances to be able to convert the nozzle back and forth between a setting for efficient noise suppression operation and a different setting for maximum thrust operation without regard to noise level.

With the foregoing in view the present invention is directly broadly to the provision of improved noise suppression nozzles for jet propulsion engines having noise suppression elements which may also be retractable. In the preferred embodiment the invention provides an adjustable nozzle exit opening in combination with retractable stream divider elements disposable in the discharge stream at the nozzle exit. A related objective is the co-ordination of the retraction and extension movement of the stream divider elements with movement of orifice elements by which the area of the nozzle opening is varied, with the object of establishing approximately the same exit area with the stream divider elements extended to their noise suppression setting as when these elements are retracted to gain thrust. In this way the nozzle delivers the maximum thrust of which it is capable in the noise suppression setting, and the greater maximum thrust in its alternative or cruise setting. Such a nozzle adapted for thrust reversal provisions constitutes a further object.

Other objects are to provide especially formed stream divider elements which are efficient to mix the jet gases with ambient air with minimum turbulence noise; and to

provide noise suppression nozzles of a compact form meeting the foregoing objectives.

According to the present invention a jet propulsion engine of the type specified is provided with noise suppression means comprising a plurality of stream divider elements of generally plate-like form mounted on said nozzle to extend inwardly from the periphery of the exit thereof at spaced-apart locations therearound, and disposed generally perpendicularly to the direction of discharge, said stream divider elements having openings therein permitting restricted passage of discharge gases therethrough for admixture with ambient air drawn inwardly across the rear faces of the respective elements by virtue of said discharge.

The invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a rear perspective view of a jet propulsion engine discharge nozzle embodying the features of the present invention, the view showing the stream divider elements extended, the exit diameter enlarged and the thrust reversal means retracted; and

Figure 2 is a fragmentary rear perspective view of one of the stream divider elements of the invention and the associated orifice-defining leaves.

Referring now to the drawings, it is to be noted that the Figures correspond to Figures 1, 9 and 11 of the parent Application No. 19877/58 (Serial No. 859,993) to which reference should be made for further details of the constructional features and the method of operation of the parts. In order to facilitate such cross reference, the reference numerals used on the present drawings identify similar parts to those shown in the drawings of the parent application.

Referring now to Figure 1 of the drawings it will be evident that the main body of the jet engine is omitted from the drawings, which illustrate only the discharge nozzle portion thereof. The outer cowl 10 of the engine terminates rearwardly in a ring section comprising a plurality of alternately overlapping and overlapped leaves 12 sometimes referred to in the art as "turkey feathers" and which are pivoted at their forward edges about transverse axes extending generally tangentially to the periphery of the cowl where it is joined by the leaved ring section.

The discharge nozzle comprises two duct forming members, one of which is a tube 36, shown in part in Figure 2, and the other a rearwardly tapered tail cone 38 which projects somewhat beyond the nozzle exit and extends forwardly to merge with a central cylindrical island member (not shown) mounted within the engine. In this embodiment of the invention the provision of a tail cone in the engine is optional.

The cowl 10 and ring section comprising leaves 12 form a protective outer housing for certain engine components, including actuating mechanism for the noise suppression elements of this embodiment of the present invention and for the leaves 12. Also, such cowl furnishes a protective housing for a rearwardly projectable thrust reversal sleeve 42 of a known type which is described in detail in the parent application.

The rear edge of the cylindrical exhaust tube 36 is located somewhat forwardly of the rear edge of the leaved cowl section 12. The nozzle discharge orifice is formed between the tail cone 38 and a contractable and expansible leaved extension ring 36' of the tube 36. Such extension is formed by leaves 36'a pivotally mounted at regularly spaced intervals around the rear end of tube 36, and overlapped by intermediately situated leaves 36'b similarly mounted on the end of the tube. As will be evident the orifice exit may be expanded by outward swinging of the leaves to the position shown in Figures 1 and 2, for example, and contracted by inward swinging of the leaves as previously described. Longitudinal edge flanges on the leaves 36'b bear slidably against the outside surfaces of the overlapped leaves 36'a, whereas similar outwardly directed flanges on the longitudinal edges of the overlapped leaves 36'a bear slidably against the inside surfaces of the adjacent leaves 36'b. These flanges form a seal and provide a positive means limiting outward swinging of the leaves to the expanded condition of the ring section 36'. Hook-like retainer elements 35 on the projecting ends of the leaves 36'a hold the adjacent leaves 36'b against them in all positions of the former.

Pivotally mounted on a transverse axis at the rear edge of each of the overlapped leaves 36'a is a retractable stream divider element in the form of a tab 246 which is basically trapezoidally shaped. The tab is of generally elongated form and the broader of its two ends is connected to the leaf 36'a and for that purpose carries sleeve elements 48 aligned transversely of the nozzle with a sleeve element 50 mounted on the end of the sleeve 36'a. A hinge pin 52 extends through the aligned elements 48 and 50. The tab 246 is thus mounted for swinging between a retracted position, projecting forwardly of the nozzle and lying flatly in contact with the inside surface of the supporting leaf 36'a and an extended position directed transversely of the nozzle discharge in substantially perpendicular relationship with the supporting leaf, as shown in Figures 1 and 2.

In this embodiment the stream divider elements extend inwardly toward the nozzle axis from a location substantially at the outside periphery of the exit so as to prevent

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a sheath of discharge gases at the exit which would surround the branch streams formed by the stream dividers and would thereby obstruct free inflow of surrounding air into the spaces between the separate branch streams.

In order to actuate the tab 246 between these positions a crank arm 54 is rigidly connected with the base of the tab and forms an obtuse angle to the plane of the tab, projecting generally outwardly in relation to the nozzle. This crank arm is connected pivotally to one end of a rod 56, the opposite end of which is pivotally connected to the rearwardly projecting end of a guided link 28. The link 28 is provided with a straight longitudinal slot 30 engaged for guidance by stationary rollers 32 and 34 spaced apart lengthwise of the slot and fixed to tube 36. A hydraulic jack 58 or other suitable actuator connected to the longitudinally movable link 28 moves the connecting rod 56 lengthwise of the nozzle. In the forwardly drawn position of this connecting link, as shown in Figures 1 and 2, the crank arm 54 is swung forwardly, and in this position of the link and rod 56 a protuberance 56¹ on the inner side of the rod generally intermediate its ends bears against the outside face of the supporting leaf 36¹a. In this position of the elements, the leaf 36¹a is held in its outwardly swung position and the tab 246 in its extended position, as shown in Figures 1 and 2. For that purpose the protuberance 56¹, the leaf 36¹a, the crank 54, and the rod 56 form a rigid truss structure by virtue of the fact that the forward end of the rod is anchored by its pivotal connection to the link 28, and the forward end of the leaf 36¹a is anchored by its pivotal connection to the end of the tube 36.

An outwardly projecting cam element 60 on the leaf 36¹a has a sloping surface interposed in the path of the protuberance 56¹ and engaged thereby when the rod 56 is moved rearwardly by the actuator 58. By moving the link 28 rearwardly of the engine, the crank 54 causes the tab 246 to swing forwardly and outwardly into contact with the inside face of the leaf 36¹a and the protuberance 56¹ advances into contact with the cam 60. When the tab 246 contacts the leaf, with the protuberance 56¹ then bearing against the cam 60, the leaf is swung inwardly by virtue of such cam engagement. The leaf is rigidly held in this position by the rigid truss structure formed by the protuberance 56¹, the cam 60, the leaf 36¹a, the crank 54, and the rod 56.

In the retracted tab position of the parts, the contracted nozzle exit is defined by the inwardly deflected leaves 36¹a and 36¹b, and the opposite surface of the tail cone 38 and is of generally annular form un-

interrupted by noise suppression tabs. This represents the maximum thrust or cruise setting of the nozzle. The orifice opening yielding that result may be readily determined by well known jet engine design considerations. In the position of the parts shown in Figures 1 and 2, the nozzle exit is expanded by outward deflection of leaves 36¹a and 36¹b in order to compensate for the decrease of exit opening area otherwise produced by extension of the noise suppression tabs 246 across the opening. It is found that the angle of swing of the leaves should be such that the nozzle exit opening is approximately the same with the tabs extended as it is with the tabs retracted. In this manner any reduction of nozzle efficiency when the noise suppression tabs are extended is minimized.

It will be noted that the actuating mechanism shown in this embodiment of the invention produces automatic co-ordination between the setting of the noise suppression tabs and that of the leaves determining the area of the nozzle exit. However, it will be evident that the tabs may be alternatively actuated independently of the means for varying nozzle exit opening. With the type of actuating and connecting mechanism shown in this embodiment it will be apparent that the leaves are actuated conjointly between their alternative position as are the tabs.

The described mechanism is of lightweight construction, enables the nozzle to be of circular form for purposes of compactness and efficiency, and is readily adapted for installation on available engine types. While in the illustration twelve retractable noise suppressor tabs are employed and these are of trapezoidal form which project inwardly to a location near the tail cone 38, it will be evident that a different number of tabs may be used and that their specific form or shape may vary. The form of the invention shown is also applicable to engines which do not have a tail cone such as the tail cone 38 in the illustration, inasmuch as the support of the tabs and the compensating movement of duct-forming parts defining the nozzle exit does not depend upon the presence of a tail cone.

The construction of the tab 246 is shown in detail in Figure 2. The tab 246 is of flanged construction with the web or body of the tab provided with a number of small apertures 246c. These apertures pass some of the hot gases from the engine for admixture with cool outside air flowing inwardly across the rearward face of the tab between the flanges 246a and 246b. This arrangement further reduces engine noise, apparently for the reason that it warms the inwardly flowing outside air before its mixture with the divisional streams flowing between the tabs, so that the noise-producing

turbulence of the mixture of such streams with the outside air is lessened. Also, there may be the additional effect of hot gases blowing through the apertures 246c imparting a rearward component of motion to the inwardly flowing outside air so that when it passes over the lips of the flanges and into contact with the gas streams, it is already moving rearwardly with appreciable velocity. As a result, the reduced differential rearward speed of the hot gases and the outside air when they first come together lessens the turbulence of their mixture and thereby further reduces the attendant noise.

15 WHAT WE CLAIM IS:—

1. A jet propulsion engine of the gas stream thrust reaction type having a discharge nozzle with an exit through which exhaust gases are discharged to produce forward thrust, noise suppression means comprising a plurality of stream divider elements of generally plate-like form mounted on said nozzle to extend inwardly from the periphery of the exit thereof at spaced-apart locations therearound, and disposed generally perpendicularly to the direction of discharge, said

stream divider elements having openings therein permitting restricted passage of discharge gases therethrough for admixture with ambient air drawn inwardly across the rear faces of the respective elements by virtue of said discharge. 30

2. A jet propulsion engine as claimed in Claim 1, wherein the stream divider elements comprise substantially flat plates having openings therein, and flanges projecting from the rear faces of such plates on opposite side edges thereof to channelize ambient air flowing inwardly of the nozzle across such faces. 35 40

3. A jet propulsion engine as claimed in Claim 1 or 2, having means supporting and actuating the stream divider elements for pivotal movement thereof into retracted positions extending generally parallel to the engine discharge. 45

For the Applicants:

F. J. CLEVELAND & COMPANY,
Chartered Patent Agents,
29, Southampton Buildings,
Chancery Lane,
London, W.C.2.

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the Original on a reduced scale.

